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A computational model was used to improve the learnability of an Air Force document, doubling recall and greatly improving recruits' mental representation of the content. Kintsch's computer model of reading was applied to a 1000 word Air Force text on the Air Force's role in Vietnam War. Principles of the model were used to identify 40 text locations where recruits would have to make inferences if they were to have a coherent mental representation of the text. Each location was then repaired, and the repaired text was then tested for learnability against the original text in two experiments. In Experiment 1, free recall was doubled for the repaired text. In the second experiment, 120 recruits' 66-part mental representations for 12 important text concepts were measured, and compared with the mental representations of the text's author, and of 7 independent subject matter experts. The author and the experts' mental representations correlated about .80. For recruits who read the repaired text, their mental representations correlated with the author and experts about .55, $p < .05$. But recruits who read the original text correlated with the author and experts only about .10. These results suggest that the computational model can be used to improve the learnability of Air Force texts. Individual differences tests of inferencing ability were developed.

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Annual Technical Report

The Effect on Learning of Inferences in Instructional Text

Bruce K. Britton

University of Georgia

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Annual Technical Report

The Effect on Learning of Inferences in Instructional Text

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Abstract

A computational model was used to improve the learnability of an Air Force document, doubling recall and greatly improving recruits' mental representation of the content. Kintsch's computer model of reading was applied to a 1000 word Air Force text on the Air Force's role in Vietnam War. Principles of the model were used to identify 40 text locations where recruits would have to make inferences if they were to have a coherent mental representation of the text. Each location was then repaired, and the repaired text was then tested for learnability against the original text in two experiments. In Experiment 1, free recall was doubled for the repaired text. In the second experiment, 120 recruits' 66-part mental representations for 12 important text concepts were measured, and compared with the mental representations of the text's author, and of 7 independent subject matter experts. The author and the experts' mental representations correlated about .80. For recruits who read the repaired text, their mental representations correlated with the author and experts about .55, $p < .05$. But recruits who read the original text correlated with the author and experts only about .10. These results suggest that the computational model can be used to improve the learnability of Air Force texts. Individual differences tests of inferencing ability were developed.

Annual Technical Report

The Effect on Learning of Inferences in Instructional Text

Bruce K. Britton

The objectives of this project were to use a computational model of reading to find out how to improve learning from Air Force texts, and to develop an individual differences model based on the mental processes specified in the model.

Table 1

Specific Aims

The top level goal is to produce a broadly useful way of improving Air Force recruits' learning from instructional text. Since about half of Air Force training is based on text, any large improvement in learning from text will have an appreciable impact on the effectiveness and efficiency of Air Force training. The project is based on Walter Kintsch's computer model of text comprehension. The specific aims are to:

1. Analyze two Air Force texts (one on the history of the air war in Vietnam, and one on aerospace doctrine) using computer programs developed by Thea Turner and Walter Kintsch.

2. Use the theoretical principles underlying the programs to produce:

   (a) a tree diagram of the mental representation that the Kintsch program produces after reading the text, corresponding to the mental representation produced by a recruit with the same abilities as are embodied in the Kintsch program,

   (b) a tree diagram of the mental representation the writer intended the recruit to have after reading the text, corresponding to the representation produced by a skilled reader.

3. Add abilities to the Kintsch program to produce diagrams of the mental representations of recruits intermediate between highly skilled readers and those only as skilled as the Kintsch program. (Most of these additions will require operator assistance to run.) The creation of these additions will serve as a heuristic device to achieve goals 4, 5, and 6 below.

4. Develop new theoretically motivated individual differences tests (these will measure the abilities added to the program in goal 3). Air Force recruits in the Experimental Testing Facility at Lackland Air Force Base will be used to develop the tests, under the supervision of Patrick Kyllonen's group.

5. Develop a model relating the abilities measured by the individual differences tests to the recruits' learning.

6. Revise the texts so that they do not require the individual differences abilities specified in goal 3 (or require less of the abilities).

7. Perform empirical tests of:

   (a) the individual differences tests of goal 4, combined as in the model of goal 5, for their efficacy in predicting recruits' learning of the original Air Force texts,

   (b) the modified versions of the texts (developed in goal 6) for their efficacy in creating the desired representation of the texts.

Current Status of the Research

Accomplished Objectives

Using Kintsch's computational model of reading (Kintsch & Van Dijk, 1978; Miller & Kintsch, 1980), we have successfully analyzed and rewritten an Air Force text to greatly improve its learning: Free recall was doubled, and the shape of the recruits' mental representation of the rewritten text was much closer to the representation of the text's author (and of 7 independent subject matter experts) than the recruits' representation of the original text. The progress of this work is described in narrative form in the next section.

Narrative Description of the Accomplished Objectives. We used Kintsch's model to analyze a text in order to find the locations in the text at which the model had a problem in establishing coherence while "reading" the text. Our idea was that, if Kintsch's model was a good simulation of what a person does when he reads, then the locations in the text where Kintsch's model has coherence problems should be the same locations where the person will have problems.

If we then repaired each of those coherence problems, by revising the text to make coherence easy to establish, then the model would no longer have those problems. And of course the person who is reading should no longer have those problems either, if the model is a good model of the person. The result should be that a person reading the revised text should understand and learn it better.

So, our first step was to analyze the text to find out the locations of coherence problems. We used the procedure shown in Table 2.

Table 2

Model-Based Analysis Procedure

1. Input: "Naive-Literal" Proposition List.

2. When coherence fails (no argument overlap): the program stops.

3. We count an inference call there.

4. Then we add a proposition to the list to establish coherence (bridge the gap).

5. We restart the program: it runs (through the added proposition) until either:

   (a) coherence fails again (go to 3) or

   (b) the program finishes the passage.

6. The output is a count of the number of inference calls.

7. Also the program outputs the number of reinstatements (another problem in establishing coherence).

Study 1: Correlations Between Inference Calls and Recall

In our first study (Britton, Van Dusen, Glynn & Hemphill, 1990) we tried to predict text recall with those numbers. Specifically, we correlated those inference counts and reinstatement counts with recall and short answer test performance, in 8 texts revised by others. The texts were 8 high school history texts 600-1000 words long. Each text was recalled by 24 undergraduates. We found correlations around -.8. Table 3 shows the data for one such correlation.

Table 3

Example of a Correlation Between Recall and Inference Calls

Passage/rewriters	Immediate recall (%)	Inference Calls
Vietnam/composition instructors	28	3
Korea/composition instructors	25	3
Vietnam/discourse researchers	23	4
Vietnam/original	22	4
Korea/discourse researchers	20	8
Vietnam/Time-Life	20	8
Korea/original	14	8
Korea/Time-Life	13	13

Table 4 shows the entire set of correlations for free recall and short answer tests, fo. inference calls and for reinstatements. Table 3 shows the data points for the upper left-most correlation in Table 4 (-.89).

Table 4

Inference Call Correlations with Recall

	Free Recall		Short Answer	
	Immediate	Delayed	Immediate	Delayed
Inference calls	-.89*	-.85*	-.78*	-.76*
Reinstatements	-.80*	-.75*	-.71*	-.70*

*$p < .05$.

These results showed we could predict recall and short answer performance quite well with numbers that the Kintsch model calculates from the text.

Study 2: Experimental Demonstration of Effects of Repairing Inference Calls on Mental Representations

Our next step was to experimentally demonstrate that the model could be used to control the properties of a text to make it more learnable. To do this, we chose a new text and revised it using the principles of the Kintsch program. Table 5 shows an example from the very beginning of the text, which was a 1000 word Air Force training document on Air Force history by Major Robert Ehrhart, a history professor at the U. S. Air Force Academy. The top panel shows the title and the first sentence from the Original text.

Table 5

Example of Original Text and Revision

Original Text

Title: Air War in the North, 1965

By the fall of 1964, Americans in both Saigon and Washington had begun to focus on Hanoi as the source of the continuing problem in the South.

Text with Inferences in Parentheses

Title: Air War in North (Vietnam) 1965

By the fall of 1964 (causing events in 1965), Americans in both Saigon and Washington had begun to focus on Hanoi (Capitol of North Vietnam) as the source of the continuing problem in the South.

Text with Inferences Incorporated into Text

Title: Air War in North Vietnam, 1965

By the beginning of 1965, Americans in both Saigon and Washington had begun to focus on Hanoi, Capitol of North Vietnam, as the source of the continuing problem in the South.

The first sentence of the original text does not cohere with the title, according to the Kintsch model, since there is no argument overlap, that is, there are no repeated words. To establish coherence we added to the proposition list (which is the input to Kintsch's program) the propositions shown in the middle panel of Table 5 (in parentheses in Englished form.) And also we rewrote the text to incorporate those propositions; the result of the rewriting at this stage looked like what is shown in the bottom panel of Table 5.

Our goal in this revision was to establish coherence wherever the author intended there to be coherence. That is, we thought the author intended people to connect late 1964 with 1965, and to know that this sentence was about North Vietnam, the same North Vietnam referred to in the title. We did this for the whole text. We found 40 such coherence problems. We called the result the Principled Revision because we analyzed it and rewrote it according to the principles of the Kintsch program.

I also wrote, in advance, a Heuristic Revision, based on my own rules of thumb for writing clear text. I expected this to be an upper control for the Principled Revision, showing what could be done if I had complete freedom to rewrite in the best way I knew how.

Then we gave each version to 22 undergraduate students. The results are shown in Table 6.

Table 6

Results of Study 2

	Original Version	Principled Revision	Heuristic Revision
Free Recall (Number of Propositions)	29	63*	57*
Reading Rate (words per minute)	112	128*	112
Length (words)	1030	1302	1027
Reading Time (minutes)	9.2	10.2	9.2
Propositions Recalled per minute of Study Time	3.2	6.1*	6.2*

*$p < .05$, different from original.

The recruits recalled twice as much from the Principled and Heuristic Revisions as from the Original. They read the Principled Revision at a faster rate. Even though the Principled Revision was longer, people didn't take significantly longer to read it. And they recalled more propositions per unit time from it.

Most importantly, we also compared the shape of people's mental representations with that of the author and other experts. To do this we picked 12 terms from the text, shown in Table 7. We created all possible pairs of these terms, which is 66 pairs in all.

Table 7

Some Main Terms from the Texts

Members of Johnson Administration

President Johnson

Civilian Advisers

Military Advisers

Robert McNamara

Maxwell Taylor

Military Strategy

Graduated Response Strategy

Psychological

Rolling Thunder

Success

Failure

We asked separate groups of 40 Air Force Recruits to read each passage and then, from memory, to rate each pair of terms for relatedness on a 7-point scale: 66 pairs in all. Then we asked the author - Major Ehrhart - to read his original text, and do the rating; this gave us the author's mental representation. Also we asked seven local experts (two military historians, a former ambassador, etc.) to read the text and give us their mental representations. The average correlations between the author and the experts was .80.

Then we correlated the 66 items for the 3 groups of recruits with the author and the expert group. The results are shown in Table 8.

Table 8

Correlations of Experts' Cognitive Structures with Novices

(All Experts read Original)

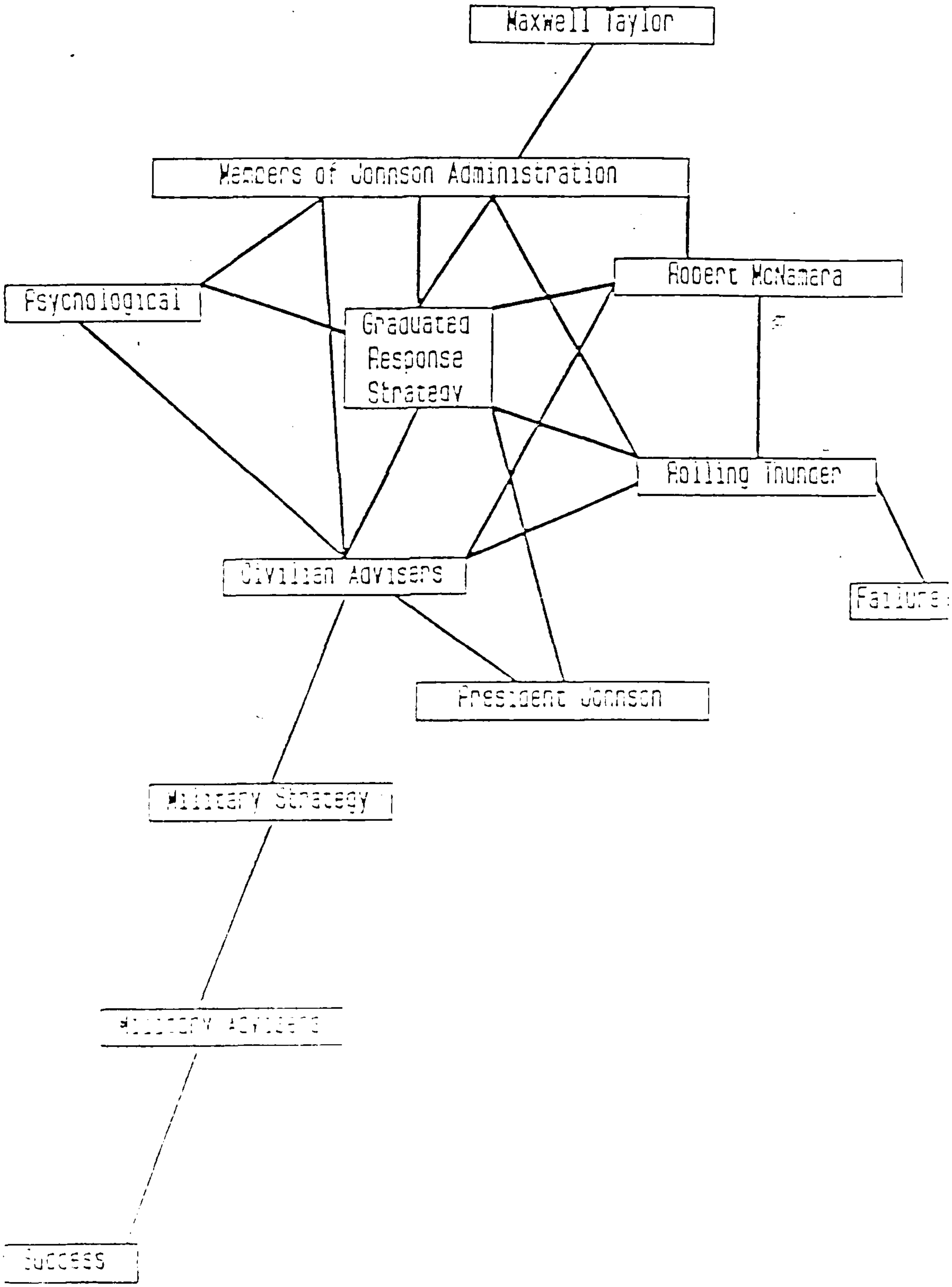
	Original Version	Principled Revision	Heuristic Revision
Ehrhart	.08	.52*	.61*
Experts (n=7)	.10	.55*	.61*
1. Ambassador Hillenbrandt	.02	.38*	.44*
2. UGA Military Historian 1	.16	.56*	.55*
3. UGA Military Historian 2	.08	.54*	.59*
4. Major Eunice (AFROTC Commandant and Instructor)	.11	.51*	.59*
5. Military Employee in Classified Job	.12	.55*	.66*
6. High Level Military Employee	.03	.41*	.40*
7. Amateur Military Historian	.12	.54*	.62*

*p < .05

As you can see, the recruits who read the Principled and Heuristic revisions had a mental representation closer to that intended by the author than did those who read the Original - the author's text. That is, the mental representation of the people who read the Principled Revision was closer to the author's own mental representation than the representation of those who read the Original was. The results with the rest of the experts were the same. It appears that our Principled Revision implemented the author's intentions better than the author.

We can make a map of the mental structure from these data (Schvaneveldt, 1989) using Schvaneveldt's Pathfinder program. Figure 1 shows the map for the experts.

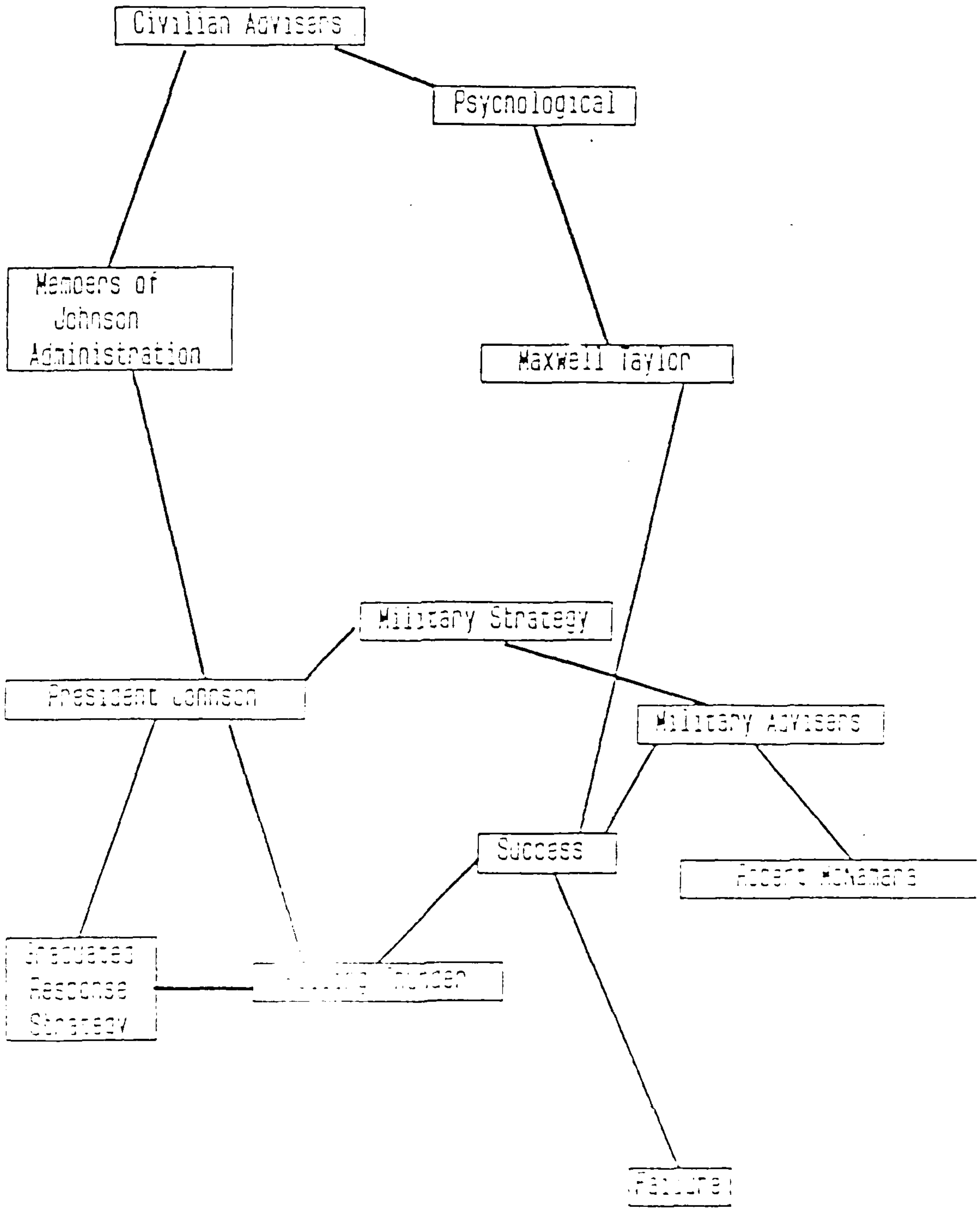
Figure 1



The map makes good sense if you've read the passage, or know this period of history. The passage is centered about the "graduated response strategy" in the center; arrayed around it are the various proposers of it and users and the result – the operation code-named "Rolling Thunder" – with Rolling Thunder linked to "failure". And "success" is way off on the periphery of the representation.

But those who read the Original had the map shown in Figure 2.

Figure 2



They think Rolling Thunder was a success: An outcome approximately equivalent to reading the Bible and concluding that Satan was the Good Guy.

The conclusion is that Kintsch's model did very well for the purposes intended here.

The Appendix contains a full report on these two studies.

Partly Accomplished Objectives

Theoretically motivated individual differences tests of the abilities needed to read the Original text, according to Kintsch's model, have been developed. These include tests of inference making ability, tests of the ability to detect that there is a need for an inference to be made, and tests of prior knowledge. Criterion tests of learning from the text, and of inference-making in the text have also been developed.

In two visits to test recruits, pilot tests and interviews were conducted and the tests have been refined and improved. Another visit is planned for October 1990, and probably the rest of the proposed visits will be required before the tests are ready. This is mainly because the tests for the construction-integration ability have not yet been successful. This test is based on a connectionist paradigm. A visit to Kintsch's laboratory to discuss this problem is planned for December, 1990. It should be noted that development of the construction-integration tests is frankly a highly speculative undertaking. We know of no individual differences tests of connectionistic abilities (J. McClelland, personal communication, August, 1989; D. Rumelhart, personal communication, August 1989) so unbroken ground is being plowed here.

Working memory tests will be used from the battery developed by the LAMP program.

Current Status of Uncompleted Research Objectives

The main uncompleted research objectives are (a) to relate the mental representation diagram produced by the Kintsch program to the mental representation of the reader (Specific Aims 2a + b), (b) to develop a model relating the individual differences to learning (Aim 5), and (c) perform the empirical tests (Aim 7). These empirical tests can be conducted as soon as the rest of the individual differences tests are ready. The model of the effects of individual differences on learning is based on the mediating and moderating effects of the variables measured by the individual differences tests.

The other uncompleted objective has to do with the mental representations produced by the Kintsch model. Here a substantial problem has arisen along with an opportunity, in that the hierarchical tree representation of the Miller and Kintsch (1980) model appears inadequate for many texts, including the one we have revised. Instead, a more flexible representation is required, corresponding to a network. A network is more general and flexible than a tree because any tree can be represented as a suitably constrained network, and a network can also represent structures other than trees.

Fortunately, just such a network representation is now available, in a model developed by Althea Turner. She worked with Kintsch for many years, and her model is descended from his. Use of her model was foreshadowed in Specific Aim 1. I am now working with her on a publishable version of (a) the model and (b) an experiment in which her model accounted for about 30% of the variance in recall of about 400 individual propositions in four texts.

Working with Thea, I am applying her model to Air Force text to produce a network representation of it. This will then be used in accomplishing Specific Aims 2a and b.

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